LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
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Technical Note **LIGO-T1500062-v13** 2022/09/15

Pcal End Station Power Sensor Responsivity Ratio Measurements: Procedures and Log

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End Station: EX Date: 9/15/2022

Measurements Performed By: Dripta Y Tony

Items to take to the end station for the measurements:

- Working Standard (in protective case)
- CDS Laptop
- PD Satellite Box (blue box), D1300368
- Long (25') DB9 cable
- DB9/BNC male to DB9 female temperature cable
- BNC cable
- A Fluke handheld digital voltmeter
- Martel calibrated voltage source, banana-to-BNC adapter cable, and charger/AC adapter
- IR-only laser glasses (for use ONLY if work in the ALS laser enclosure, which could expose the VEA to green laser light, will not be ongoing in parallel)
- IR viewing cards: high-power (white) and low power (orange)
- 1.5 mm allen key to remove input aperture cover from Working Standard
- Handheld IR Viewer

Before (or after) going to the End Station

- Check the calibration of the Keithley Model 2100 voltmeter using the Martel Calibrated Voltage source at following three different voltages (the same one that will be taken to the end station). Note: use negative polarity.
  1. (**-4 V**): with Martel = -3.9998 V on Keithley 2100 DVM
  2. (**-2 V**): with Martel = -2.0000 V on Keithley 2100 DVM
  3. (**0 V**):with Martel = 0.036 mV V on Keithley 2100 DVM

1 Before starting Pcal work in VEA

- ✓ Make sure that the IFO's ISC LOCK Gaurdian is in a down or idle state, and that it will not try to auto lock.
- ✓ Close the ALS laser shutter via the MEDM screen (Sitemap/LSC/Shutters/ISCTX(Y) green beam.)

- Check that SEI ENV is set to Maintenance Mode to Shut Off Sensor correction (The Operator should have done this for Tuesday Maintenance but check anyways.)
- Call the Control Room (ext. 202) to notify them of the laser status change.
- Transition VEA to **LASER HAZARD** status.

1.1 Before starting the measurements

- Record Rx enclosure Digital Thermometer ("Outside" display) = 18.4 deg. C
- Record Rx enclosure Digital Thermometer (" Inside" display) = 17.8 deg. C
- Turn PCAL Interlock bypass to the ON position.
- Set shutter to local
- Disable all three excitations on the Pcal MEDM screen (Sitemap/Cal/PcalX(Y)/Excitation):
  1. H(L)1:CAL-PCALX(Y)_SWEPT_SINE
  2. H(L)1:CAL-PCALX(Y)_OSC_SUM
  3. H(L)1:CAL-INJ_MASTER_SW
- Ensure that the ETM pointing is in the "aligned" state.
- Remove cover from Rx enclosure and verify that Pcal beam spots are close to their nominal locations (centered on the Rx sensor input aperture). If they are not, adjust their positions using the final steering mirrors inside the output section of the Tx module enclosure.
- Open a GPS Clock window (type `gpsclock &` in a terminal window).
- Open **StripTool** (type `StripTool &` in a terminal window) and display the following four sensor outputs. Always verify that signals are stable before recording time series.
  1. **H(L)1:CAL-PCALX(Y)_TX_PD_WATTS_OUTMON**
  2. **H(L)1:CAL-PCALX(Y)_RX_PD_WATTS_OUTMON**
  3. **H(L)1:CAL-PCALX(Y)_WS_PD_OUTMON**
  4. **H(L)1:CAL-PCALX(Y)_OFS_PD_OUTMON**

2 Calibration measurements

2.1 Preliminary measurements

2.1.1 Calibrate the Working standard channel

- Connect **Martel Calibrated Voltage Source** to INPUT 1 on the ***BNC to DB9*** interface module mounted in the Pcal transmitter pylon. Note: use negative polarity, and adjust Range to 0.000 to allow up to 4V.
- Inject the three following input voltages for 15 seconds each and record the GPS time and the output level displayed on the StripTool for each 15 second interval.
  1. (**-4 V**): GPS Start Time 1347316837; Voltage = -3.996 V
  2. (**-2 V**): GPS Start Time 1347316782; Voltage = -1.9998 V
  3. (**0 V**): GPS Start Time 1347316737; Voltage = -0.0002 V

2.1.2 Record Optical Follower Servo (OFS) settings

- Offset: [illegible] V 3.9
- Gain: 41 dB
- OFS PD: [illegible] V -3.884

2.1.3 Record Working Standard temperature

- Measure the Working Standard on-board temperature using at DVM at the BNC output of the DB9/BNC to DB9 cable. Multiply the voltage by 100 to obtain the temperature in K.
  - GPS time: 1347315703
  - WS on-board temperature: 298.7 K

2.2 Power sensor measurements

- Connect the Pcal Satellite Box PD MON output to INPUT 1 on the ***BNC to DB9*** interface module mounted in the Pcal transmitter pylon.
- Record GPS start and end times and nominal StripTool output levels during the measurements.

2.2.1 Measurement 1:

- Block the OUTER beam with a razor blade beam block in the Tx module.
- Loop cable around something to ensure that the sphere doesn't fall when the cable is stepped on.

- Place the WS in the INNER beam in the Tx module.

WS in the INNER beam in the Tx module.					
GPS times		StripTool outputs			
Start Time #1	1347 319 [illegible] 543	TxPD	~~1.01723~~	W	0.5310
Duration	240 seconds	WSPD	~~2.3678~~	V	-1.2328
End Time #1	1347 319 [illegible] 783	OFSPD	~~7.4076~~	V	-3.884

2.2.2 Measurement 2:

- Move the beam block to the INNER beam in the Tx module.
- Move the WS to the OUTER beam in the Tx module.

WS in the OUTER beam in the Tx module.					
GPS times		StripTool outputs			
Start Time #2	1347 319 [illegible] 946	TxPD	~~1.01734~~	W	0.5312
Duration	240 seconds	WSPD	~~2.3780~~	V	-1.236
End Time #2	1347 32[illegible] [illegible] 186	OFSPD	~~7.402~~	V	-3.884

2.2.3 Measurement 3:

- Leave the WS in the OUTER beam in the Tx module with the INNER beam blocked.
- Close the shutter in the Tx module.

WS in the OUTER beam in the Tx module. Shutter CLOSED.					
GPS times		StripTool outputs			
Start Time #3	1347 ~~317 7845~~ 320 232	TxPD	-2.02e-5	W	
Duration	60 seconds	WSPD	0.003	V	
End Time #3	1347 ~~317 8445~~ 320 292	OFSPD	-0.009	V	

2.2.4 Measurement 4:

- Leave the block in the INNER beam in the Tx module.
- Replace the Rx sensor with the WS in the Rx module.
- Keep shutter closed until WS Sphere has been fully replaced with RX Sphere.

WS in the Rx module. INNER beam blocked in the Tx module.				
GPS times 320 544		StripTool outputs		
Start Time #4	1347 ~~318 261~~	TxPD	0.5312	W
Duration	240 seconds	WSPD	-1.22103	V
End Time #4	1347 ~~318 501~~ 320 784	OFSPD	-3.884	V

2.2.5 Measurement 5:

- Move the block to the OUTER beam in the Tx module.

WS in the Rx module. OUTER beam blocked in the Tx module.				
GPS times		StripTool outputs		
Start Time #5	1347 320 835	TxPD	0.5310	W
Duration	240 seconds	WSPD	-1.2156	V
End Time #5	1347 321 075	OFSPD	-3.883	V

2.2.6 Measurement 6:

- CLOSE the shutter in the Tx module.

WS in the Rx module. Shutter CLOSED in the Tx module.				
GPS times		StripTool outputs		
Start Time #6	1347 321 140	TxPD	7.55e-5	W
Duration	60 seconds	WSPD	0.0032	V
End Time #6	1347 321 200	OFSPD	-0.0109	V

2.2.7 Measurement 7:

- OPEN the shutter in the Tx module.
- Leave the beam block in the OUTER beam in the Tx module.
- Replace the WS with the Rx sensor in the Rx module.

OUTER beam blocked in the Tx module. Rx sensor in the Rx module.				
GPS times		StripTool outputs		
Start Time #7	1347 321 634	TxPD	0.531326	W
Duration	240 seconds	RxPD	0.260424	W
End Time #7	1347 321 874	OFSPD	-3.88384	V

2.2.8 Measurement 8:

- Move the beam block to the INNER beam in the Tx module.

INNER beam blocked in the Tx module. Rx sensor in the Rx module.				
GPS times		StripTool outputs		
Start Time #8	1347 321 927	TxPD	0.5311	W
Duration	240 seconds	RxPD	+ 0.2612	W
End Time #8	1347322 167	OFSPD	- 3.884	V

2.2.9 Measurement 9:

- CLOSE the shutter in the Tx module.

Shutter CLOSED in the Tx module. Inner beam blocked.				
GPS times		StripTool outputs		
Start Time #9	1347 322 201	TxPD	-7.63e-5	W
Duration	60 seconds	RxPD	- 4.48e-5	W
End Time #9	1347322 261	OFSPD	-0.0097	V

2.3 When measurements are finished.

2.3.1 Before leaving VEA

1. Remove the beam block from the INNER beam in the Tx module.
2. OPEN the shutter in the Tx module.
3. Set the shutter control to **Remote** on interface module.
4. Verify that the Pcal beam spots are centered on the input aperture of the Rx sensor (photograph spot locations on white card).

5. Replace the enclosure covers on both the Tx & Rx modules
6. Re-enable the three excitations on the Pcal MEDM screen (if applicable)
7. Turn the interlock bypass to **OFF**.
8. Transition VEA back LASER SAFE status
9. Call the Control Room (ext. 202) to notify them of the laser status change and that they may take the SEI ENV to CALM is they wish to start Locking.

2.3.2 To complete the end station measurement effort

- Analyze the data (see Section 3) and upload results to the SVN.
- Make an aLog entry; append images of the beam spots at the Rx power sensor aperture, and add a pointer to the measurements results in the SVN.

3 Data Retrieval and calculations

For more details on how to run these calculations, refer to T1900758.

3.1 Data Acquisition, Plots and Report

1. Make sure the SVN directory
   `/ligo/svncommon/CalSVN/aligocalibration/trunk/Projects/PhotonCalibrator/scripts/O4/pcalEndstationPy`
   is installed on the machine where you are working.
   Change to this directory.
   Note: A description of the Photon Calibrator SVN directory structure and instructions for checking out the whole Pcal repository can be found in `LIGO-T1500095`.
2. Execute the command `svn update` to make sure you have the latest versions of the scripts.
3. Execute the command `kinit albert.einstein@LIGO.ORG` to establish connection to the external data server. This will be required for obtaining data later.
4. Open the `config.py` Python script.
   (a) Enter the appropriate IFO location and arm and date code.
   (b) Enter the GPS times of the various measurements as you have listed them in this procedure.
   (c) Save `config.py`
5. In the command terminal run `python3 generate_measurement_data.py`

6. It will create a folder named `tDYYYYMMDD` in the appropriate end-station-specific directory, e.g. for LHOY
`/ligo/svncommon/CalSVN/aligocalibration/trunk/Projects/PhotonCalibrator/measurements/LHO_EndY`

7. The data is fetched from the server and written into .json files in the `DYYYYMMDD` directory along with a config.py copy. It also generates and saves plots of the times series of the ratios. Make sure the plots are satisfactory.

8. If the data appears to be valid, change the name of the directory from `tDYYYYMMDD` to `DYYYYMMDD`. If the data is corrupted in some way (e.g. a large glitch in the data or a data dropout), change the directory name to `xDYYYYMMDD`. This vetoes the directory from trend documents published at a later date.

3.2 Rx responsivity trends

1. Copy the `EStrends.py` script from `/ligo/svncommon/CalSVN/aligocalibration/trunk/Project PhotonCalibrator/scripts/O4/pcalTrendsPy` to `/ligo/svncommon/CalSVN/aligocalibratic trunk/Projects/PhotonCalibrator/measurements`

2. In `/ligo/svncommon/CalSVN/aligocalibration/trunk/Projects/PhotonCalibrator/measurements` run `python3 EStrends.py` with the endstation as an extra argument, e.g. `python3 EStrends.py LHO_EndY`

3. It creates a trends plot `EStrends.pdf` for the Rx responsivity in the measurement directory. For LHOY, it creates the trends plot in `/ligo/svncommon/CalSVN/aligocalibration/trunk Projects/PhotonCalibrator/measurements/LHO_EndY`

3.3 Force Coefficient Calculation

1. If the data was not vetoed, then navigate to the directory containing the scripts for making force coefficient trends, in `/ligo/svncommon/CalSVN/aligocalibration/trunk/Project PhotonCalibrator/scripts/O4/pcalTrendsPy`

2. In the command terminal run `python3 pcalPublishReports.py` with the endstation as an extra argument, e.g. `python3 pcalPublishReports.py LHO_EndY`

3. It creates a force coefficient trend document back in the measurements directory. For LHOY, there will be one named `LHO_EndY_FC_Report.pdf` and another named `LHO_EndY_PD_Report.pdf`.

3.4 Commit the new files to the SVN

1. In the terminal window, execute the following commands (Refer to T1500095 for details) from the
`.../PhotonCalibrator/measurements/LHO(LLO)_EndX(Y)`
folder (Refer to T1500095 for details.)

- `svn add DYYYYMMDD`
- `svn commit -m "message, e.g.  person committing files"`
- `svn update`

2. Run the last two items on the list from `.../PhotonCalibrator/scripts/pcalTrendsPy` to add the new trend documents to the svn.

Add to alog

Add the generated FC and PD trend plots to an alog, along with a scan of this procedure and the beam alignment photo.